STRONG

Methods of Determining the Costs of Manufacturing

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METHODS OF DETERMINING THE COSTS OF MANUFACTURING

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED METHODS OF DETERMINING THE COSTS OF MANUFACTURING

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

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METHODS OF DETERMINING THE COSTS OF MANUFACTURING

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I. INTRODUCTION.

Advancement along the lines of cost finding has been most marked during the last five years. It seems reasonable, therefore, in the following discussion, to omit any reference to the desultory development occurring before this period. Conditions relating to cost finding methods can best be summarized by reviewing briefly the ideas on the subject that have come to be generally accepted during this time.

(a) Factory Routine.

Factory routine is directly responsible for efficient production, as repeated procedure in the accomplishment of any task tends to make the operation a habit, and thus to do away with the waste of energy and effort suffered during the first accomplishment of the task. Such a condition of affairs in a factory is highly desirable, for with no losses the total energy is made available for the creation of salable output. Factory routine is the direct result of factory organization.

(b) Factory Organization.

In the perfectly organized factory, every act of every worker is ordered and regulated by the system, and enforced by the routine which is the product and outcome of the system. From past reasoning it is seen that to organize the factory is to apply added energy to the creation of output.

To go further into the reasons for factory organization, take the common case of a successful factory producing

a commodity in good demand, financially sound, and growing steadily. There are thousands of such factories in America today, many of them managed by the second or third generation of the same family, thoroughly established, each well known in its line of manufacture. Such a factory is likely to be more efficient in some details than in others, and not at all times working with perfect smoothness, but yet fairly satisfactory in results if carefully followed and watched. Why change the routine of such a successful factory? Close acquaintance with and careful analysis of the workings of such a factory always reveal one leading manager, who may or may not rank as such, who exercises a general supervision over the conduct of affairs, and virtually carries the works on his shoulders, and is overtaxed by responsibilities, voluntarily assumed when clearly seen.

This general manager of the imperfectly organized factory has, first of all, the improvement in the quality of the product in view. Next to this, the improvements of production elements, which will increase the factory's labor-hour efficiency require his attention. The third division of the general manager's labors is the hateful drudgery of adjusting the faulty mechanism of the factory routine, so that this small delay, or that evidence of hurtful friction, or these little clashes between minor officials may be alleviated, smoothed over and adjusted so that the factory product may continue to be produced at a minimum expense. Growth of business sooner or later makes it imperative that the manager rid himself of this

third division of his labor. To define the duties of subordinates seems to the manager the first step toward this end. Finally, the manager realizes that each act of every subordinate must be recorded, with the time of performance, because nothing short of this time-record vouching the doing of all things ordered done, will keep his subordinates up to the mark of efficiency. When the dictator of the unorganized factory reaches this perception of the necessity of defining the duties of all subordinates and recording all their performances, he at once becomes aware that the same reasoning applies to things as well as to men in the factory and this perception leads immediately to factory organization, in which duties and functions are clearly and rigidly defined, performance records are regularly made, and factory products are located when at rest, and traced when moved.

(c) Cost Finding.

First as to the true and vital objective of cost finding: The cost finding organs and functions together comprise certain things manipulated so as to furnish a more or less close approximation of the total cash-outlay cost of a factory product. The cost-keeper hopes by ascertaining the cost of past productions to be able to accurately predict the cost of future productions. It is evident that if the factory is not at least fairly well organized, that past performance is not a safe basis for future expectation.

So factory organization and factory cost finding are one and inseparable, and must thrive or decline together,

though sometimes cost finding will be most in view, and sometimes factory organization will hold the more prominent position.

II. A REVIEW.

A. General Review.

(a) The Importance of Cost Finding.

It is now fully realized that production costs can be reduced only by increasing vigilance in scrutinizing the minutely-divided items of production cost. It is of no avail to know merely that an article costs more than need be; before the cost can be reduced, the precise production detail which can be diminished in cost must be known, so that appropriate remedies can be intelligently applied where they are needed.

In this view, accurate cost finding becomes of the highest importance to the factory and the factory manager.

(b) The Interdependence of Manufacturers.

As recently as 1898 few factory managers, when approached, showed any willingness to place their cost-finding methods and practice before the public, being loath to place before competitors the results of their own hard and costly labors in the form of fully worked out systems, which rendered satisfactory returns. It has become to be the view now, however,

that what helps all helps each, that what hinders one, hurts all. To convince ourselves that gains and losses are not solely individual affairs, we have only to reason as follows: The manufacturer must have buyers. Factory practice begins with the creation of the production order, and the production order must come from some one who has money to pay for the completed product. Hence the benefit to one is for the welfare of all; He who makes good use of his production possibilities must always be a better buyer and a more abundant and promptly-paying purchaser than the less thrifty one who fails in economy.

This view, which makes the continuing prosperity of the individual absolutely dependent on the prosperity of the community at large, has made those managers who are most fully aware of the value of intelligent factory organization most ready to tell all they know.

(c) Manufacturers Should Exhibit Their Practice.

In the broad view of the situation, the wide open and fully revealed factory is not only not surprising, but is the only rational determination of the matter. The successful factory manager is fully aware that he has reached a commercial certainty for his own future, and so becomes a sure and promptly-paying consumer of the products of other factories, only through a long succession of partial failures, which leading by slow and painful steps to final triumph, often hindered his own past purchases. The able factory manager also knows well the value of that indirect patronage which enables his customers to buy more largely of him and pay more promptly because they are themselves

better producers and command wider markets and quicker returns than if they were less well equipped than he himself, which makes for factory economy.

(d) The Factory Manager's Best Informant.

As to the form in which cost-finding theory can be best studied, it seems that actual applications of this theory, proved by practice to give profitable results, must be far more valuable than the mere general views and opinions of any single factory accountant, no matter how able and expert he may be. The study of the applied and concrete thing is easier than the application of unembodied possibilities, however correct may be the theories on which they are founded. Moreover, a comparison of two different methods for obtaining the same desired result invariably leads to succeeding improvements.

(e) Improved Factory Management.

In factory accounting there is no disposition shown to return to lump sums and aggregations of prime costs differing but slightly in origin. On the contrary, the plainly manifested tendency is toward that entire separation and resolution of costs into final distinct elements, which alone can give the works manager a commanding grasp of his entire labor costs. When a cost-keeper begins to see clearly that he cannot reduce cost without detailed information, he is dismayed by the multitude of form spaces demanded for the separate item records which he sees he is forced to make, and appalled by the vision of an interminable succession of cost forms, and so seeks to make combination cards which will reduce the number of his form blanks, and the

combination forms thus evolved often show great ingenuity, and appear at first sight to be very valuable aids.

(f) Shop Forms.

Just as one machine is like another machine, so cost-finding machinery invariably goes through the same simplifying processes that are applied to special machine tools for metal working. Highly ingenious combinations, difficult of production, delicate and liable to vagaries of action, are replaced by devices of marked simplicity, easily understood, and certain to accomplish what is desired. In one stage of machine-tool development, carefully-devised combined tools were in favor, and lathes and milling machines were made in one, as were slatters and drillers. These combinations have wholly disappeared. This is the rule with all machines and industrial appliances. Ingenious combinations at first, simplicity of elements, separation of processes, and multiplication of production steps, at last. It is better to use many, sure simple aids than to use fewer complicated ones. Following this general law, the experienced cost-keeper uses a large number of simple forms, avoids combinations, and adapts a final policy of separate forms for separate items.

B. Economic Review.

(a) Labor Costs.

All costs, of all manufacturers, are without exception labor costs. This is evidently true, for in the process of manufacturing labor is applied to the products of nature, but until the labor is applied, such natural values as minerals in the mine, standing timber, sunlight, air, rainfall, a fertile soil, falling streams, etc. produce no part of the world's commercial value.

(b) The Specialized Factors.

This broad assertion, that labor costs are the only costs of manufacture at large, is not true when applied to the individual manufacturer. On the contrary, when the modern scheme of specializing factory product is carried out, the rough stores of such a factory are always the finished product of one or many previous producers, whose labor costs of operation and profits are included with their preceding stores cost, in the price which the factory manager must pay for his raw material. For the final manufacturer simply buys labor with the profits of a previous manufacturer added.

III. PRINCIPLES OF ORGANIZATION AND COST FINDING.

A. The Basic Principles of Organization.

Fig. 1 is intended to show the prime elements which go to make up any factory organization. No matter how large the business may grow the result is simply a subdivision of these prime elements, resulting in new departments and new authorities. The prime elements are, in the Manufacturing Section, Purchasing, Stores and Manufacture, and in the Commercial Section, Accounting, Advertising and Sales, with a general manager at the head of an connecting the two.

This figure also shows, first, that the stockholders are simply elements belonging to the general public, that immediately after this, the election of directors sets into action the first internal factor in the body, which is then divided into different functioning powers by the election of executive officers. The final circulation of the business is kept active by the auditor or comptroller and is divided into four factors, viz: Administration, Labor, Up-keep and Material Expense, the dotted lines within the oval indicating to what extent this circulation enters into the organization as a whole. Labor permeates through all departments, Material not extending beyond the Purchasing and Accounting departments; while the Up-keep expense permeates through all departments and is compared, as is indicated by the

the second dotted line within the oval, of both labor and material. Administrative expense, as indicated by the dotted circle, is but a local circulation of expenditure in the Administrative Section. It is also shown that the avenues of correspondence with the outside world are, incoming correspondence, first, of the stockholders, second, the material receipts, third, the commercial receipts. The outgoing correspondences are, commercial disbursements in payment for material received, and manufactured output which comes back in the form of commercial receipts.

THE PRIME ORGANIZATION ELEMENT OF AN INDUSTRIAL BODY

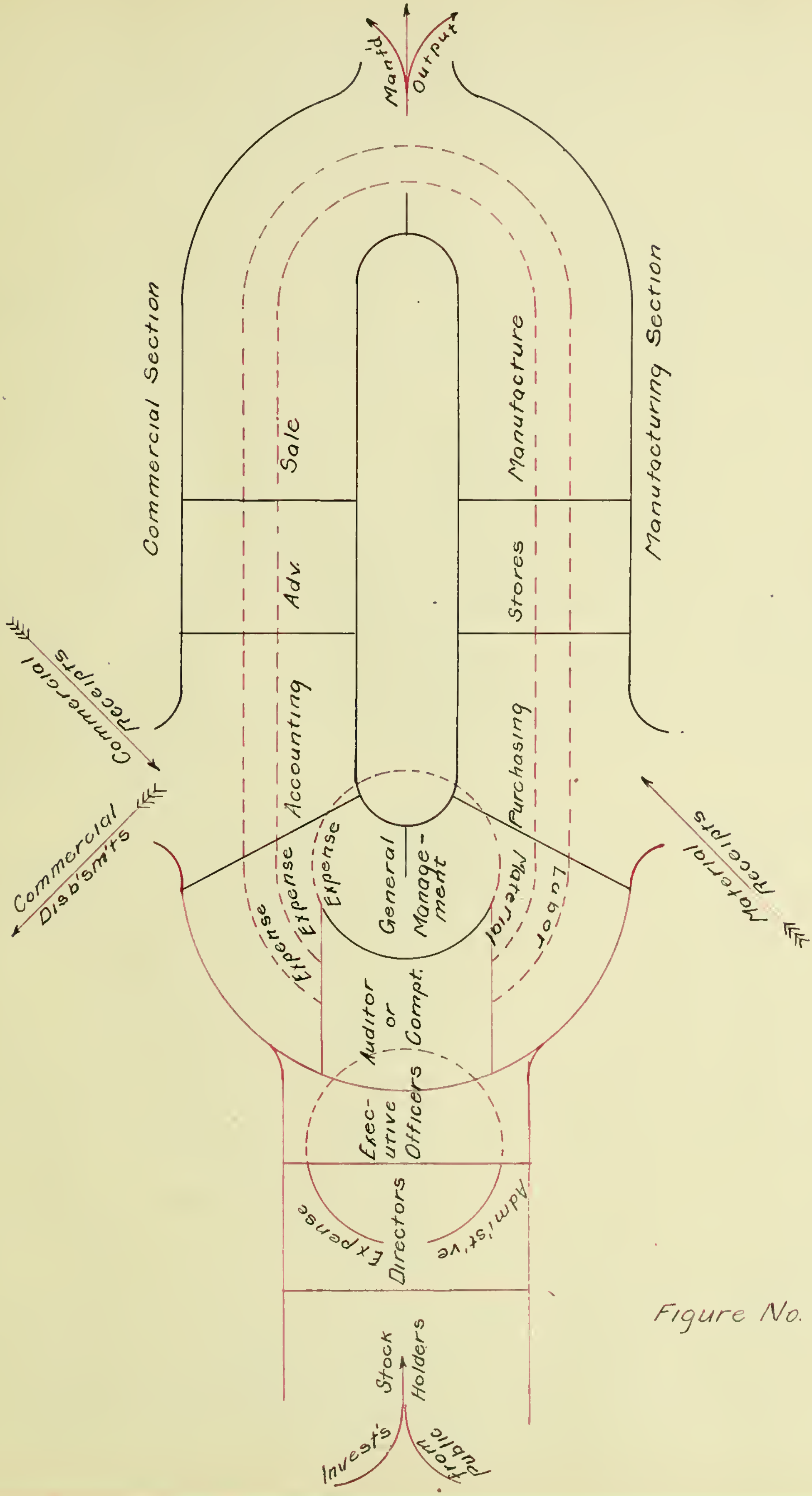

Figure No. 1

B. The Two Main Types of Cost Finding Systems Used in Manufacturing, and an Explanation of the Principles Involved in Such Systems.

There are two main types of cost finding systems used in manufacturing work. (1) Those used by machine tool builders and builders of highly finished articles who buy their stock in exact sizes and as needed. (2) Those used by agricultural and harvesting machinery companies whose stock is bought before the production season, the amount depending upon the figures of the previous year's business and the indications for the one just at hand. It will be shown later on in this discussion that the above classification is based on a clerical difference only, and that the methods of obtaining actual shop costs may be the same in both cases.

To determine the cost of any article manufactured it is necessary to know three things: the actual cost of labor, the actual cost of material and the actual cost of burden.

By labor is meant the total labor employed in the plant. This includes the productive and non-productive labor, in other words labor which enters directly into the immediate output of the product together with such labor as that performed by sweepers, oilers, roustabouts, etc.

The subject of materials is used to refer to such things as enter directly into the finished product. That is, materials such as oil, waste, etc. used in running the production machinery together with materials for repairs charged under

burden, the next subject to be discussed.

Under the head of burden is charged everything that goes to make up the cost, not included in the divisions, labor and materials. The charges in this burden account are itemized to a greater or less extent depending altogether on the personnel of the company and are independent of the class of manufacturing. The following is a list of items which might be placed under this head: interest on plant, barn and team account, insurance, taxes and general operating expense. Under the latter head are charged such items as the following: lubricating material, waste, babbitt, soap, stock, asbestos, lathe, draughtsman's supplies, repairs, belting, rope, tool steel, paint, shop sundries, small tools, borax, fire-brick, etc. and freight on the above, power, light, heat and freight, all bills for gas and electricity, all coal for steam and heat, grinding material and freight, all emery and other wheels used in the grinding shop, blacksmith shop fuel and freight, pig iron, scrap iron for foundry and freight, factory and office supplies, and additions to plant.

In any class of manufacturing the cost of labor and material is obtained from the various shop forms used and the purchasing departments respectively. Again from a summation of all other charges against factory production the total burden charge is determined.

There are two methods of distributing this total burden charge in common use, known as the Percentage Burden Plan and the Hourly Burden Plan. Under the Percentage Burden Plan the total burden for a given period is divided by the total direct

wages for the same period. The resulting ratio, treated as a percentage, gives a factor which, when multiplied by the direct wages on any piece of work, will give the burden belonging to the work, and this added to the direct wage will give the final labor cost. To illustrate, call the above percentage x. Then if the direct wage on an article be $20, then 20 times x = 20 x or the burden belonging to the particular article. Then 20 x dollars = share of total burden to be applied to the article considered.

With the Hourly Burden Plan the total burden for a given time is divided by the total number of hours of labor for that time. This quotient is a charge per hour which is to be added to each hour's wage on a given piece of work. The difference between cost finding systems, which led to their classification as above, is due directly to the fact that in any case of manufacture the quoted price is based on estimated cost. This estimated cost is then compared with the actual cost to give data for future estimates. In the case of the manufacturing of agricultural machinery the estimate is made for a year's output at one time. For example, the cost-keeper estimates the labor and material cost of 100 machines and then multiplies this figure by the number of machines to be manufactured. The actual cost for this output and consequently the cost per machine is not known until the completion of the output estimated for. On the other hand in the case of the machine tool and engine builder, a price and consequently an estimated cost is set on each order turned out, and it is necessary to check the estimated cost with the actual cost as soon as the product is finished. Therefore the

clerical work in the latter case is considerable in excess of that required in the former, due to the fact that actual costs must be continually compared with estimated costs.

C. Graphic Aids to Cost Finding.

At the present time actual shop cost figures cannot be obtained, or even approximated, graphically. However professional cost system experts find the graphical presentation of a complex problem an invaluable aid to its solution. In general only relations or ratios can be expressed graphically. That is, actual costs cannot be shown although the inspection of a diagram may show whether the costs are reasonable or, on the other hand, higher than necessary. That graphic illustration also facilitates the study of elements and aids the mind in grasping the problem as a whole will be evident upon a study of the following illustrations. As an exponent of graphic illustration in this country may be cited the C. W. Hunt Company of Brighton, N. Y. This company presents the ranking of authorities and the factory routine on six System Charts, each 18" long by 11 1/2" wide. The general scheme of this "System Chart" construction, is to represent both individuals and things by circles containing identifying titles and to so locate these agency circles on the chart sheet as to enable them to be connected by lines of influence, action, association and control; so as to clearly indicate the general and specific relations of one to another, and

where important, the precise functions of individuals. Arrow heads in the connecting lines show the direction of the communication, influence or product passing from one agent to another.

Fig. 2 shows that the three prime expenses, general expense, labor expense and material expense, already discussed, flow into two separate channels, one Commercial Expense; the other, Manufacturing Expense, and that these two avenues of expenditure then join in a final summary of "Cost to Make and Sell." It is evident from an inspection of this figure that commercial and manufacturing expenses should be kept as separate accounts.

Fig. 3 shows the relative value of the different accounts corresponding to a year's business. A comparison of succeeding diagrams, like the above, would serve as a check on efficient production.

DIAGRAM SHOWING EXPENSE DIVISION

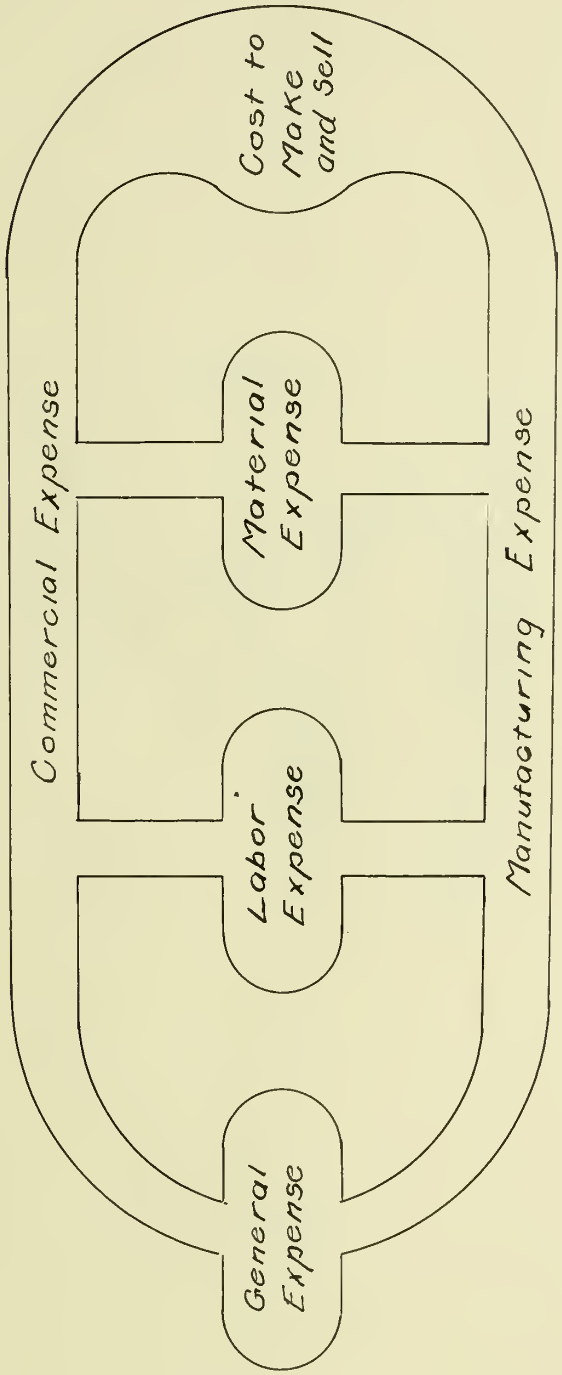

Figure No. 2

A GRAPHIC BALANCE

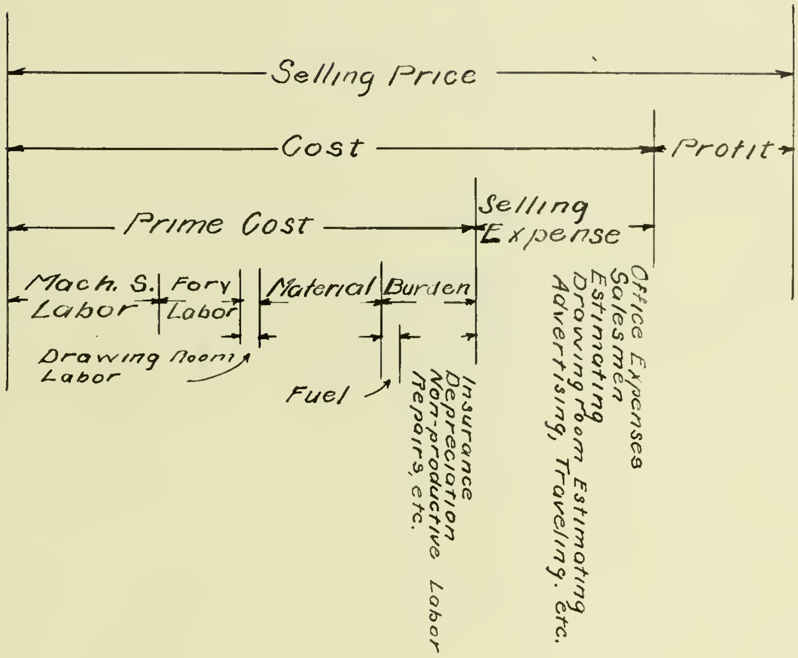

Figure No. 3

D. A Comparison of Features in the Cost Finding Systems of Company's A, B, C, D, E, F, G.**

(1) The methods and shop forms used in obtaining the cost of material.

In any line of manufacture the original production order is filled out in the main office upon receipt of the customers order. This order is then turned over to the shop superintendent and the bill of material and stock requisition on the stores department or purchasing department and sub or component orders are made out. Table #1 gives a list of items for which space is provided in the production order for each of the above companies.

** For glossary of principle terms and abbreviations used see page 27.

Table No. 1

PRINCIPAL PRODUCTION ORDER							
Item Companies	A	B	C	D	E	F	G
No.	—	—	—	—	—	—	—
For	—				—	—	—
Date Entered	—	—	—	—	—	—	—
Issued by	—						
Countersigned	—	—					
Receiving stamp	—						
Sub ordered, date	—						
Specefication O.K.	—						
Stock ordered, date	—						
Ship to		—					
Via.		—					
Bill to		—					
Quantity		—	—			—	
Date Shipped		—					
Customers order, $\frac{3}{4}$ of entire space	—	—	—			—	—
Shippers report on back		—					
No pieces		—					
Articles		—					
Shipping date		—					
Wt.		—					
Factory No.			—				
Receiving shop			—				
To arrive at destination			—				
Subject to				—			
Symbol indicative of type				—			
Delivery promised					—		
Lot No.					—		
Machine No					—		
Order received via.							—
Sales No.							—
Consignee							—

Features.

Factory (A). A list of material ordered under each order number together with a daily production report from each department is recorded in a production record book.

Factory (B). In this case the special production record card is done away with and a production record is made directly on the production order. Each shop receives a copy of this order.

Factory (C). The production order is type-written and sent direct to shop. There is no fixed production order form.

Factory (D). No purchase is made except against a standing order number.

Factory (G). Purchases made continually so as to keep stores replenished ~~up~~ to a certain fixed mark.

(2) The methods and shop forms used in obtaining the cost of labor.

In four of the seven shops considered a time clock is used to obtain a record of actual working time each day. In case of either day or piece work separate cards are made by the time clerk and issued to each workman for each separate article, or lot of articles, designated by the same mark or symbol. A record from these time cards is made each day. In the shops considered there exist three main methods of paying labor. Plain

day pay, single workman piece-rate, and gang piece-rate. The first form of labor pay is the fixed hour rate. Every day worker has his individual hour-wage rate. The second form of labor pay is the single workman piece-rate, which in the majority of cases was a "premium" rate. If the work is finished inside the time fixed by the rate-fixer for the operation, then the workman obtains the high rate of pay; if the workman does not finish the job inside of the rate-fixer's time, then the workman is paid the low rate only. In each shop considered a distinctive time card was used for each separate form of production labor. The use of differently colored time cards leads to instant recognition of a card's function and is a growing practice.

(3) Routine Forms.

In any shop organization the routine forms form a large percentage of total forms used. The following list gives a few of the titles under which such forms are classed: Watchman's Report, Department Order on Storeroom, Memorandum of Merchandise Credit, Tool-room Report, Damage Report, Tags of various kinds, Indexes, Notification of Shipment, Passes, Department Receipt Form, Shipping Ticket, Accident Report.

(4) A Routine Feature.

It is absolutely necessary for factory purposes that

three things should always be known of each individual factory production, great or small, simple or compound. First, under what production order the component is produced; second, where the component is located at any instant; third, what the state of progress is. All this must be known concerning sub-productions. In regard to principle productions, it is needful to know what components of each are completed, and in what stage of progress the incomplete component parts are, at any instant of inquiry.

The C. B. Cottrell & Sons Company, Westerley, Rhode Island, makers of printing presses, have thousands of components in progress in their factory, many of them changing their location from one department to another at the same time. The Cottrell method of solving the above problem is as follows; when the component enters a factory department a small, stiff card, bearing the component symbol and order number, is placed in a grooved tray, which for example, call the department. When this department operation is completed and the component must go to another department, the card is selected at a glance from the tray, representing the department, the date written on the back with the department number, and the card put in another tray representing the department to which the component is to be taken next.

IV. A PROPOSED SYSTEM OF COST FINDING.

A. Applied to Cost of Instruction in Shop Practice at the University of Illinois.

Table No. 2 is a cost sheet applicable to finding the cost of instruction in the shops at the University. The division of cost is indicated.

GLOSSARY.

MAIN PRODUCTION ORDER:	Original production order. An order by the Sales Department on the Manufacturing Department.
SUB PRODUCTION ORDER or COMPONENT PRODUCTION ORDER:	An order made from the main production order, one for each component of a principal production order.
ROUTINE:	Repeated shop procedure.
BILL OF MATERIAL:	A list of all material required for total order.
ROUTINE FORMS:	All forms used in obtaining data other than that of cost.

		PRODUCT	HELP EMPLOYED
COMPANY (A)	Deere & Co.	Agricult. Implements	750
COMPANY (B)	Link Belt & Eng. Co.	Engineering Concern	325
COMPANY (C)	Biglow Co.	Boilers	200
COMPANY (D)	C.B.Cottrell & Sons	Printing Presses	450
COMPANY (E)	Potter & Johnston	Machine Tools	120
COMPANY (F)	Wells Bros. Co.	Tapers, Dies, Reamers	185
COMPANY (G)	E.W.Hunt Co.	Electric Locomotives, Steam Hoisting Engines.	

Table No. 2

COST SHEET

A—Labor

From_ _ _ _ _ _ _ _ _ _ _ _ _ 190_ _ _ _ _ _ _ _ _ _ _ To_ _ _ _ _ _ _ _ 190_ _

Departments			Non-Productive			
			Dept. Heads	Asst. Heads	Clerks	Day Work
Manufacturing Expense	Non-Productive Dept.	Purchasing				
		Stores				
		Supt's Office				
		Drawing				
		Pattern				
		Tool Room				
		Total				
	Productive Dept.	Wood Shop				
		Foundry				
		Forge				
		Machine Shop				
		Total				

B-Material

Shop Practice Material					Office Supplies				Shop Supplies		
Mach S.	Wood S.	Found.	Forge	Total	Staty.	Print.	Office Equipt.	Total	Oils	Fuel	Tot.

C - General Expense

Taxes	Insurance	Light	Heat	Power	Repairs	
					Labor	Material

D- Shop Improvement Purchased

Machinery + Tools	Power Equipt. + Fixturers	Total